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AUTHOR Friedman, Edward A.
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ABSTRACT

This learning module, one in a series developed in a project on "Technology and the Liberal Arts," is an introduction to emerging technological developments for information storage. A historical sketch is provided of text technologies leading up to widespread use of the typewriter toward the end of the 19th century. This is followed by an analysis of the information storage capability of microfilm. Storage technology for computer systems is then reviewed, with particular emphasis on magnetic and optical devices and on coding techniques that make text intelligible to machines. Applications of text technologies that have an impact on economics and social organizations are presented in the context of the service sector, including library, insurance office, and hospital automation. The full unit provides the basis of 2 weeks of study as part of a survey course on information technology. Exercises for students are provided. Figures and tables include diagrams of the QWERTY and DVORAK keyboards, the Braille alphabet, the American Standard Code for Information Interchange (ASCII), and a graph of changes in storage density of magnetic disk drives between 1954 and 1980. (14 references) (GL)

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Technologies For Text

by Edward A. Friedman

This module is an introduction to emerging technological developments for information storage. For students who have some background in the use of computers, the module provides an opportunity to study the impact of information technology on libraries, offices and office automation, among other service-sector applications. The module places the subject in an historical context. Students are not required to have any special background in science or mathematics.

Designed to further student understanding of technological issues, this module is one in a series developed in a project on "Technology and the Liberal Arts," which is sponsored by CIC—the Council of Independent Colleges, Washington, D.C.

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TO THE EDUCATIONAL RESOURCES INFORMATION CENTER (ERIC)."

Technological advances in just the past few decades have revolutionized many of the complex systems that guide our lives—the way we travel, for example, and how we communicate with one another, heal our sick, even the way we grow our food. As the rate of technological progress accelerates, these systems will become more complex, and new ones will evolve. Technology will continue to be a preeminent force in our lives.

As citizens in a technological society, therefore, we need to be able to make intelligent choices about how technology will affect our future lives. This requires that we have a better understanding of technology itself. We need to understand its potential and limitations. Further, we need to understand the very *process* of technology, and have a sense of its methodology and rules.

The Council of Independent Colleges has been deeply involved in these issues since 1984, in a project entitled "Technology and the Liberal Arts." Working with faculty from small liberal arts colleges, CIC has sought to integrate the study of technology and technological issues into the liberal arts curriculum. Our goal is to improve the understanding of technology on the part of undergraduate students—the future citizens of the technological society.

This course module is one in a series developed in the CIC project under a grant from the Exxon Education Foundation. Each module is designed to introduce students, particularly those not majoring in the sciences, to a technological issue or concept. In the process of completing the exercises in the modules, we also hope students will develop an idea of the methodology of technological inquiry. Our goal in publishing the modules is to make teaching materials available for use in courses across the liberal arts disciplines. We are deeply indebted to the Exxon Education Foundation and its executive director, Arnold R. Shore, for supporting this endeavor.

I want to also acknowledge the many college faculty who have participated in CIC's technology project. To each, I offer my sincere thanks for pioneering the important effort to bring technology into the mainstream of the curriculum.

Allen P. Splete
President
The Council of Independent Colleges
October 1987

In addition to the Exxon Education Foundation, the following sources have provided funding for the CIC project on Technology and the Liberal Arts: Monsanto, Pew Memorial Trust, AT&T, Ford Foundation, Consortium for the Advancement of Private Higher Education, Pfizer, and Xerox.

Technologies For Text:

Storage and Retrieval of Linguistic Records

by Edward A. Friedman

Professor of Management
Stevens Institute of Technology
Castle Point, Hoboken, New Jersey

Overview for Faculty

Text written on tablets, papyrus or paper has been an essential artifact of civilization for at least 5000 years. The materials and technologies of document preparation, storage and transmission shape our private lives as well as structure our work environments.

Within recent decades technological systems began encoding language in the form of "one's" and "zero's". This binary code is manipulated in a bewildering variety of transformations and transmissions. Most frequently, that processing is categorized under the rubric of Office Automation. Unfortunately this conveys an image of attempts to replace clerks who generate typed documents and cope with chaotic file cabinets with cold-hearted machines. This is a limited perspective.

New technologies are propelling an information processing revolution for the human species. This revolution is of fundamental importance to historians, linguists, sociologists, anthropologists, economists, political scientists, psychologists and all others for whom the evolution of society and the ability of humankind to cope with change is a concern.

Given the growing preoccupation in society with computers, we should stress that while this unit involves computers, they are not the fundamental focus. Emphasis here is on "information" —its storage, processing, transmission and retrieval. This unit only deals with a portion of that topic, primarily storage. Hence it is even more important to state explicitly that the context is not that of

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computer science but of human behavior.

Developments of automation and computer processing applied to manufacturing are easily presented with an aura of mystery and excitement. Efficiency and productivity increases in automotive production are readily perceived. The fascination of futuristic robots welding and painting new car bodies stirs a feeling of wonder. There is a poetic sense of completion in seeing the process of automation, that began with Henry Ford's first Model T assembly line in 1914, evolve into an almost humanless enterprise.

The dramatic impact of information technology on our daily lives and on the service sector in particular is more difficult to discern. Even a definition of information technology is elusive. It is difficult to identify information technology and to describe its changing characteristics. Nevertheless, a premise of this presentation is that information technology is as tangible as automated manufacturing. In terms of the history of civilization, it may have greater significance since it relates more closely to people rather than to things.

To date, recognition of information technology as an independent entity has been peripheral. Office automation is perceived as a technology for the lowest level workers, not for the bosses. In universities information science is relegated to colleges of library science that have not been in the mainstream. The more weighty and prestigious subject of Management Information Systems is seen as a specialty of computer science or of management studies.

A major breakthrough, however, which has occurred is information technology becoming an intrinsic aspect of cognitive studies. A symbiotic relationship is forming between those who design elaborate microelectronic processing networks for supercomputers and cognitive scientists who are attempting to model neural networks of brain function. There are also computer implementations of instructional material based upon hypotheses of cognitive scientists who are probing learning theory.

Similar unions with other disciplines have not yet taken place. The economics of information remains a fledgling pursuit and the impact of information technology on most other disciplines awaits development.

What follows immediately is an historical sketch, beginning in ancient times, of text technologies that leads up to the widespread use of the typewriter toward the end of the nineteenth century. This is followed by an analysis of the information storage capability of microfilm.

In dealing with storage technologies for computer systems both magnetic and optical devices are introduced. The emphasis is on coding techniques that make text intelligible to machines. A useful example of text coding that is presented is the Braille system used to transmit information to the blind.

Applications of text technologies which have an impact on economics and on social organizations are presented in the context of the service sector. The specific areas are Library Automation, Insurance Office Automation, and Hospital Automation.

No specific prerequisites are required for the study of these materials. It is anticipated that they could be of interest to undergraduates from freshman through senior year, with sophomore or junior students the most likely audience.

The material could be part of a stand-

alone course on information technology or used as a section of a course in a traditional discipline.

A number of "hooks" exist that allow the unit to be pulled naturally into various courses. Some of the connections are as follows:

historical material—history or anthropology
magnetic and optical devices—physics
coding techniques—mathematics
man-machine interface—psychology
service sector applications—economics, political science, sociology, business and management.

The full unit provides the basis of two full weeks of study in a three credit course as part of a survey course on information technology. Depending on faculty and student interest, the unit could be used for approximately four weeks of study with supplementary readings and/or student project assignments.

In summary, this unit attempts to provide examples of quantitative thinking that are readily accessible to nonscience or mathematics students. It also attempts to develop understanding of some technological artifacts systems and their role in social process. Through college faculty who focus on this domain, it is hoped that information technology will become a more central theme in the intellectual lives of those faculty as well as their students.

Introduction for Students

There is an interesting assortment of technologies for text. Systems such as alphabets or well-defined pictograms allow conceptualization of text, distinct from verbalized language. These systems can be coded into other forms such as Morse Code for telegraphic communications or Braille embossing for tactile identification by the blind. In recent times, strings of one's and zero's have been feeding the memories and processors of digital computers with the raw material for text generation.

Recorded alphabets, pictographic images, telegraphic messages, embossed Braille symbols, and printed computer output all require media for visual presentation. Media constitute another category among the technologies for text. These can range from clay tablets and papyrus to paper, photographic film, and screens of cathode ray tubes. The codes for text are also stored in a non-visual form on media such as magnetic tapes while awaiting computer processing into visual representations.

Could we place the entire Iliad on a piece of microfilm smaller than a postage stamp? Could the Iliad be stored in the memory bank of a digital watch?

A third category of text technology encompasses systems and tools that provide connections between humans and storage and processing devices. Examples include chisels, pens, typewriters, and voice-activated computers.

These various systems and artifacts provide a wide assortment of text technologies varying in durability, transportability, physical dimensions and cost. A text that has been represented in almost all manifestations of these technologies is Homer's *Iliad*.

The form in which the *Iliad* appears in

contemporary college bookstores differs markedly from its earlier manifestations. The poetry itself dates from about the eighth century B.C. and full texts probably existed in about the sixth century B.C. It was known to be an important holding, in multiple copies, in the great library of Alexandria, Egypt.

The Library of Alexandria flourished from about 290 B.C. until the early Christian era. Copies of the *Iliad*in Alexandria consisted of Greek characters inscribed on papyrus scrolls. Since the *Iliad*is made up of 16,000 lines of dactylic hexameter verse, about ten papyrus scrolls were required for the full text. This compares with the 1951 English translation of Richard Lattimore that appears in about 450 pages of modern text.

A study of technologies of text lead us to consider questions such as: Could we place the entire *Iliad*onto a microfilm sheet no larger than one page of the Lattimore translation? Could it even fit on a piece of microfilm smaller than a postage stamp? If the *Iliad*is entered into computer storage through word processing software how many floppy disks or other computer storage media are required to hold it? Could the *Iliad*be stored in the memory bank of a digital watch? If the answer today is 'no' is it likely to be possible in ten years or sometime in the more distant future?

Using optical storage of computer code it is possible to store the entire *Iliad* on space equivalent to a typical bookmark used by our grandparents to mark a favorite Homeric passage. Being able to carry the *Iliad* in the palm of one's hand will not in itself transform society. But the ability to have all the book holdings of Harvard University Library in a single dormitory lounge or in a home will surely have a great impact.

Emerging technologies of text will radically alter storage, manipulation and transmission of information. Since more than 50 percent of the workforce are information workers, these changes will be widely felt. Their impact will be on individuals, organizations, and on society. This study unit attempts to place technologies for text into an historical perspective, to examine some of the emerging technologies and to explore a few case studies. The aim of this endeavor is to provide understanding of the changing world in which we live as individuals, as citizens and as productive human beings.

For waste of scheme and toil we grieve,
For snowflakes on the wave we sigh,
For writings on the sand that leave
Naught for tomorrow's passer-by.
—"O Livermead Sands"—William Johnson Cory

Origins of Text

The major developmental steps in the history of civilization form a relatively short list. Remarkably, several of these steps were taken in Mesopotamia during the fourth millennium B.C. There is evidence that the solid wooden cart wheel and the potter's wheel were both in common use around 3400 B.C.

Early developmental steps for civilization included innovations in information technology. One, of enormous consequence, from Mesopotamia was the introduction of writing on clay tablets by Sumerians. This early text technology probably emerged to expedite record keeping for the agricultural livestock and commodities of temple estates. It also served to provide records of private

property. Initial inscriptions were pictograms representing actual physical objects. Following the emergence of image making, higher levels of abstraction came quickly, resulting eventually in the various alphabets of modern times.

Detailed analysis of the development of Sumerian writing have been possible through the study of more than a thousand clay tablets and fragments that have fortuitously survived from about 3000 B. C. The manner in which writing evolved is demonstrated by the Sumerian pictograph for water that was represented by two wavy lines. These evolved into a more abstract form as shown in Figure #1.

Later this abstract form was used to represent an entirely different concept. Sumerian scribes were struggling with the task of representing the word "in" which describes a relationship in contrast with an object. Rather than develop a complex pictogram for the concept "in", advantage was taken of the fact that the sound of the word "in" in Sumerian was similar to that of "water" (see Figure #1). Hence the same symbol was used for a second word based upon a phonetic relationship. Such abstract generalization opened the path for the development of efficient written language.

From the early pictographic representations evolved cuneiform symbols and these then were generalized into an alphabet. The alphabet with its systematic modular forms has been noted as early as 1400 BC in Ugarit (in what is now Syria). By 1100 B. C. an early Hebrew alphabet existed and a Phoenician form, from which the English alphabet was derived, was disseminated throughout the Mediterranean region after 1000 B. C.

A more recent writing system is that of the Mayans of Mexico and Central America. Mayan civilization, which flourished between 300 B. C. and A. D. 900, has provided us with written records that started in 50 B. C. The Mayan hieroglyphics are a mixture of phonetic symbols, standing for sound, and ideographs, standing for words. In some cases the same word could be written both phonetically and with an ideograph. It is only recently that the keys have been found for relatively complete translations of Mayan texts.

There appear to have been only five early, independent writing systems ever developed. These systems, from which all others derive, are the Sumerian, Egyptian, Harappan (from the Indus valley), Chinese and Mayan. Not all written language evolved from a pictographic to a more abstract form resulting in a phoenetic alphabet. A totally different cultural path was followed in Asia. The Kanjii text of Japan, for example, which is non-phonetic is still the dominant medium for written communications in that highly technological society. Its use presents a significant impediment to Japan's drive to implement fully new information technologies. Japanese offices must still employ scribes or utilize incredibly complex typewriter font sets.

Printing Technology

An excellent brief summary about the origins and impact of the printing press is contained in a volume entitled *The Technology of Man*by Derek Birdsall and Carlo M. Cipolla published in 1979 by Penshurst Press through a grant from United Technologies Corporation. This material is reproduced below:

"At the end of the 8th century in Spain

a book cost roughly as much as two cows. In the 14th century in Northern Italy, a book on medicine could cost more than half an ounce of gold and a law book more than three-and-a-half ounces of gold. Private libraries (as against the libraries of princes or abbeys) rarely contained more than 10 to 50 books; but small as they were, they represented great fortunes. Their owners always took great care to ensure that these treasures should be passed on to the right hands. Few people could afford to buy books, and students learned not from books but by listening to lectures and taking notes.

Nor did the introduction of paper in the West after the mid-13th century help, for by far the largest item in the production cost of a book was the wage of the copyist: it was a waste of money to write on such a relatively perishable material as paper. However, the spread of papermills

Any technology offers potentialities to a society. But whether and how the potentialities are exploited ultimately depends on the values and structures of that society.

in the West was important in paving the way for the invention of printing from movable type.

Like paper, printing was a Chinese invention. And as is the case of paper production, the West borrowed the initial idea of printing from the East but modified it to make it suitable for mass production. For the basic innovation in printing from movable type was a dramatic cut in production cost.

The new system was remarkable for its rapid spread. The first book printed from movable type appeared in 1445 at Mainz in what is now Germany. Within 30 years or so the new technology had reached north to Oxford, south to Palermo, west to Valencia, and east to Budapest. Within the following century it had spread to China, India, and the Americas. The first printers could print about 300 pages a day. By the beginning of the 18th century, the average had risen to over 400. By the beginning of the 18th century, two printers could pull about 2,500 pages a day. The still majestic incunabula (books from the earliest period of printing prior to 1500 A. D.) of the 15th century were followed by the less beautiful but cheaper editions of the 16th century and then , in the 17th century, by small paperbacks, calendars, hagiographies (biographies of saints), popular love stories and treatises of petty technology to be sold to a broad audience.

The public recognized the revolutionary importance of the new printing technologies. In the 19th century when Charles Babbage, the inventor of the first true calculating machine, wrote that the modern world commences with the printing press he was merely echoing the many 16th and 17th century writers who ranked printing, together with geographical discovery, among the main heralds of their new age.

Printing is a classic example of a technology whose development had a tremendous impact on society: it is also a classic example of the importance of social forces in either fostering or hindering the consequences of technological advance. Printing was invented at a time when the written word was slowly but steadily gaining ground all over Europe. The

production and diffusion of relatively inexpensive printed books (and particularly of the printed Bible) contributed largely to the further progress of literacy in Western Europe after 1500. However, three centuries after the appearance of printing, illiterates still accounted for some 35 percent of the adult population in England, about 45 percent in Belgium and France, and about 75 percent in Spain and Italy. Social and economic structures and circumstances were stumbling blocks which prevented the mass of the population from taking full advantage of a well-established technological advance.

Any technology offers potentialities to a society. But whether and how the potentialities are exploited ultimately depends on the values and structures of that society. The printing press helped spread both rationalism and dogmatism, both science and religion, both Harvey's ideas about the circulation of the blood and Galen's traditional fallacies about bloodletting. It helped circulate ideas among the cultivated, and multiplied the number of literate charlatans. Even so eminently civilized a technology as the printing press is ethically neutral."

Typewriter Technology

The printing press was an artifact that had its greatest impact on the public sector. It facilitated dissemination of religious, secular, and scientific documents intended for a large audience. While significant progress started in the public sector in the 15th century, the creation of limited copies of text for personal and business use developed more slowly. During the first half of the nineteenth century, scribes in offices were still utilizing quill pens. By 1850 some change was noted, such as steel nibs, which emerged as the preferred implement for document preparation.

During the course of the industrial revolution there was continuing interest and fascination with the development of "writing machines." Interestingly, the primary concern was not with the speed and efficiency of document preparation, but with the construction of a device that would emboss characters on paper for use by the blind.

In the archives of the British Patent Office the first attempt along these lines was recorded in 1714 when a patent was granted to an English engineer, Henry Mill. His invention was described as:

"[A]n Artificial Machine or Method for Impressing or Transcribing of Letters Singly or Progressively one after another, as in Writing, whereby all writing whatever may be Engrossed in Paper or Parchment so Neat and Exact as not to be distinguished from Print".

Neither Mill's machine nor another invented in 1784 for the blind, were manufactured. During the first half of the 19th century a few dozen unique designs for writing machines emerged in England, France, and the United States. Because of their intricate designs, it was not possible to manufacture these models at reasonable cost using existing fabrication techniques. Almost all of the early designs were intended for the production of reading materials for the visually impaired.

Methods of mass production of precision components using interchangeable parts were developed during the U. S. Civil War for the manufacture of pistols and rifles by the Colt and Remington Company. Following the Civil War, a

typewriter possessing many of the features that we still have today was developed by three inventors in Milwaukee, Wisconsin, Christopher Latham Sholes, Carlos Glidden, and Samuel W. Soule. A patent granted for their machine in 1868 included the notation that it could write well at speeds far exceeding the pen.

An agreement was reached for the production of this machine by E. Remington and Sons, gunmakers of Ilion, New York. Machines from that facility came onto the market in 1874 and were soon known as Remingtons. Some of the features of that machine included:

—cylinder for paper with line-spacing and carriage return mechanisms;

—arrangement of the type-bars so that paper is struck at the center

— actuation of the type bars by key levers and connecting wire

—printing through an inked ribbon arrangement of the keys into the QWERTY keyboard

The QWERTY keyboard is named for the first six letters that appear on the upper left row of a standard typewriter. The layout of this keyboard in 1873 was based on a need to slow typists down so that there would be an opportunity for the keys to fall back into place under the influence of gravity. Without this impediment in the early typewriters there would have been jamming of the keys by fast operators. A scientific study of typing by August Dvorak and his colleagues resulted in a keyboard in 1932 that was more nearly optimized for ease of finger movement and speed (see Figure #2: QWERTY keyboard).

Design of the Dvorak keyboard took into account the frequency with which letters appear in English usage. While business English has a different frequency distribution than Shakespearean English, analysis of each shows that E, T, O, A, S, H, N, and T are among the most frequently used letters. They all appear in the middle or "home" row of the Dvorak keyboard where they can be accessed most easily (see Figure #3: DVORAK keyboard).

A keyboard optimized for English may not be optimum for French, German, Spanish or other languages. For example, H is less common in French than in English.

An even more innovative keyboard was developed in Great Britain in the late 70s. Known as the Maltron keyboard, it has separate groups of keys for each hand. Furthermore, it has varied heights and placement of keys to take into account the length and strength of fingers, in addition to frequency of letter usage.

Typing rates on the various keyboards differ considerably. A typist who achieves 60 words per minute on a QWERTY keyboard might be able to type at rates of 70 to 90 words per minute using the Dvorak layout. An expert typist might achieve as high as 200 words per minute on a Maltron keyboard.

The Dvorak keyboard has not come into widespread use because so many people have been trained utilizing QWERTY. A large installed base consisting of millions of QWERTY keyboards worldwide is a difficult collection of artifacts to displace. Early standardization of a new technology can result in a short term and a long term fiasco. The Dvorak keyboard with its significant performance improvements is virtually unused. Some computers and typewriter companies offer it as an alternative but consumer response has been low.

In 1874 the Remington typewriters

were eagerly received in the market place. Dozens of other companies entered the market with assorted designs and by 1900 there were more than 100,000 machines in use and production was at a level of 20,000 per year. Interesting parallels could be drawn between the introduction of typewriters into offices and homes between 1895–1905 and the spread of small computers in the 1975–85.

At the time of the introduction of typewriters, those who worked in offices were almost all males (Vincent E. Giuliano of Arthur D. Little, Inc. urges us to consider the staffing of Scrooge's office in Charles Dickens' "A Christmas Carol" in order to confirm this observation in an essay on the mechanization of office work in *The Information Technology Revolution* by T. Forester, pp. 298–311).

Male domination of offices—and particularly of record keeping—dates back to the first use of writing to facilitate the processes of society. These evolved in Egypt and Sumeria in the period between 2700 B.C. and 2000 B.C. In Egypt male scribes attended rigorous schooling in order to perfect their mastery of a rush pen in applying ink to papyrus scrolls. Research shows that only children of the upper strata of society pursued the years of formal training needed to learn hieroglyphs and to perfect the needed techniques.

One of the earliest pieces of recruitment literature for an educational program comes from ancient Egypt. It reads, in part, as follows:

> "Set your heart on books!
> I'll make you love scribedom
> more than your mother,
> I'll make its beauties stand before you;
> It's the greatest of all callings,
> There's none like it in the land...
> I never saw a sculptor as envoy,
> Nor is a goldsmith ever sent."

Scribes resided at the seats of power and were treated with great respect, accorded prominent burial places and were subjects of idealized portrait statues.

The prestigious position of scribes was continued in monasteries of the Middle Ages and on into the 19th century. However, with the introduction of the typewriter there was a need for a much larger workforce as the industrial revolution caused an expansion of office activity. The "information worker sector" segment of society grew dramatically from about 6 percent of the workforce in 1880 to approximately 12 percent of the workforce in 1890 (Beniger, 1986, 12).

Many computers lie idle as individuals and organizations continue prior pre-electronic age practices.

The typewriter became an artifact for the mass production of information that paralleled the sewing machine's use in clothing manufacture. Early advertising of typewriters stressed this parallel. It stated that, "the typewriter is to the pen what the sewing machine is to the needle."

With mass production leading to lower prestige it became easier for women to be considered suitable for this new role in the workforce. The social ramifications of this development were extensive.

When typewriters became available they were often used to prepare drafts, while final versions of documents were still prepared by scribes. Failure to take full advantage of a new technology because of habits of past practice is a common phenomenon.

Many computers lie idle as individuals and organizations continue prior pre-electronic age practices.

Today we now have the paradox of keyboard use still being considered a menial pursuit and thereby creating a barrier to the use of computing and communications technologies by (particularly male) executives.

Before concluding discussion of the typewriter, the issue of a printing system to provide text for the blind deserves attention especially since that was the original motivation for the development of the typewriter. A far more simple technology of text for the blind evolved utilizing a system of raised dots. A number of different methods were introduced in the early part of the 19th century but the standard adopted is that of Louis Braille. Braille, born in Paris, published his system in 1829 at the age of twenty. It consists of a system of six possible dots arranged as two columns of three (see Table #1: the Braille alphabet). A total of 63 different combinations allow for the 26 letters of the alphabet as well as direct representation of connective words such as "and", "or", "of" , "the" and "with" as well as frequently found letter combinations such as ch, gh, etc..

Prior to automation, Braille printing could be done efficiently utilizing specialized instruments that guide the creation of pit formation on paper. In today's society, printers attached to computers can produce Braille output. Also, blind workers can enter information into computers through Braille keyboards. Automated text reading programs can give immediate aural feedback to blind computer operators so they can check for errors.

Text on Film

The vast proliferation of text documents during the 20th century has strained the ability of organizations to maintain files. Fortunately, the development of photography has made it possible to photograph text and store reduced-size images on film.

Not until 1930 did systems for storing books and documents on film became feasible and economical. One of the earliest systems was implemented by the U. S. Department of Agriculture Library in 1934.

Today, photographic storage of reduced-size images of text, known as *microform*, is widely used by government agencies, businesses, hospitals, professional offices, libraries, schools and colleges.

Microform that is recorded on a role of film is called, naturally enough, *microfilm*, while microform that is recorded on separate cards or sheets is called *microfiche*.

If you examine a photograph of a 12 inch ruler and note that it is perhaps one inch long on the film, then segments of area recorded on that film would have been compressed by a factor of 144! Consider a square formed by rulers that are each one foot in length. The one-foot-long edges would each be one inch in length on this film. Both the length and the width of the square would have been reduced by a factor of 12. The square on the film would have an area of one square

inch while the original square was one hundred forty-four square inches. These images of the square could be placed as twelve rows of twelve images each in the original square. 144 reduced images of the square on the film could be placed inside the original. This example demonstrates that a linear reduction ratio of 12 results in an area compression of 144 or 12 X 12. Similarly for any linear reduction ratio of R the area compression ratio would be R x R or R squared.

A simple experiment to illustrate this point can be implemented with a sheet of paper that is cut as a square. If this sheet is folded in half in each direction you will then have a reduced page that is one-fourth the area of the original page. Four copies of the reduced page could fit into the area of the original page.

It is essential to keep this relationship of information compression varying as the square of the reduction ratio in mind when considering microfilm. Microform that has been reduced through the photographic process by a factor of 20 has the capacity of holding 400 times as much information as the original page of text. If the reduction factor is 40 then the capacity increases to 1600 times the original amount of information.

Documents distributed by the United State Government Printing Office are often available on microfiche "cards" (really pieces of photographic film) that are about 4 inches wide and 6 inches long. Many libraries also subscribe to services that provide college catalogs on microfiche cards of this size. The borders are used to set off the images and to provide space for indentification labels. The actual space that is used for image representation is about 3 and 3/8 inches by 5 and 1/2 inches. The reduction ratio used for presentations on this medium is 24.

Discounting space reserved for borders and labels, the area available for display is —

3.375 X 5.50 = 18.56 sq. in.

Now we will examine the physical size of a standard page after it is processed with a reduction ratio of 24. The area of an 8 and 1/2 inch by 11 inch standard page is 93.5 sq. in. A reducing factor of 24 in linear dimension will bring such a page down by a factor of 576 in area to a reduced area of 93.5 sq. in. /576 or a 0.162 sq. in.

We next ask the question of how many of these reduced images will fit on the microfiche in the available space of 18.56 sq. in. Dividing that area of 18.56 sq. in. by 0.162 tells us that a maximum number of reduced images that can be held is 114.

Since there are spaces between the images and the layout does not allow for total utilization of available space, the result is a microfiche card holding 98 pages. These are laid out as 7 rows with each row holding 14 images. The number of 98 could be somewhat higher but design considerations and ease of handling have resulted in a maximum of 98 by convention for standard use.

By going through the same arithmetic steps one sees that a reduction ratio of 50 provides a maximum value of 501 images on such a fiche. In practice cards produced with reduction ratios of 50 hold 390 pages and are called "book" cards since they contain full text for a typical book. For example, a popular edition of *Typee* by Herman Melville contains 389 pages.

Since this procedure is so successful, it might seem advisable to keep going to larger and larger reduction ratios and

Since a single dot cannot represent a letter, we need to investigate the question, "How many of these smallest possible dots are required in constructing an image of a letter?" Perception studies show that in order to draw a picture of a letter with these small dots (an area of 0.00000001 square centimeters) and still have the image intelligible to human vision, a layout with about 20 dots in each direction is needed. Such a reduced letter then occupies a total area that is 400 times the area of an individual dot or 4 millionths of a square centimeter.

Actually, separation spaces are needed between dots, creating a total area of about 6 millionths of a square centimeter. This area must be compared with the size of the smallest letter that is found in standard publications such as newspapers which is a sixteenth of an inch in linear dimension or 0.16 centimeters. Such a letter occupies an area of 0.026 square centimeters. Applying the above transformation to such a letter is equivalent to an area reduction ratio of about 4,333. This corresponds to a linear reduction of about 66. If the original letters are larger, it is possible to deal with reduction ratios of up to 150. This is the practical commercial limit for what is known as *ultrafiche* that provides up to 3,200 standard sized pages on a microfiche card.

Text on Magnetic Media

Coding

Having discussed text storage on clay tablets, paper and microform, a historical review brings us next to storage on magnetic materials. In order to store information on magnetic media a new "alphabet" is needed. Instead of coding an "a" or an "A" with the marks shown on this page as might be done on clay tablets, papyrus, paper, via a typewriter, or thru microform a different formulation is needed.

Alternative coding systems for the alphabet are not new. The recording system for the blind developed by Louis Braille was one such example. In order to describe the Braille notation let's use the language of matrices. A Braille letter could be considered a 3 x 2 matrix with 3 rows and 2 columns. B(1,1) represents the position of the first row and the first column. B(2,2) would be the second row and second column. Braille notation then starts out with dots in the following places.

A - dot in B (1,1) all others empty
B - dots in B (1,1) and B (2,1) all others empty
C - dots in B (1,1) and B (1,2) all others empty
D - dots in B (1,1) , B (1,2) and B (2,2) all others empty

In the Braille notation for the alphabet a total of six locations are utilized for the possible placement of a dot. Either a dot is placed in a location or the location is left empty. A system that is a "something" or "nothing" form is said to be binary. That is to say there are two possible states a "yes" state or a "no" state. We could rewrite the Braille symbols using a notation that numbers the six positions as follows:

1 2
3 4
5 6

We could then identify the various Braille symbols with a notation that was made up of an ordered set of six numbers as follows: a dot in position 1 would be

indicated by a 1 in the first place of the ordered sextuplet, a dot in the 5 position would be noted as a 1 in the fifth position of the sextuplet while absence of a dot would be noted as a 0 in the respective position.

In this form an	A would be	(100000)
	B	(101000)
	C	(110000)
	D	(110100)
while	Z	(100111)

This form of coding is extremely useful since one's and zero's can be represented easily in physical terms. A "one" can be a switch that is on, while a "zero" is a switch that is off. Alternatively a one can be a mark that is made on an object, while a zero can be the absence of such a mark. Marks here might be made with chalk, ink, holes, or magnetic imprints. By a magnetic imprint we refer to magnetic properties of some physical environment that can be changed in local regions and later observed as "readings."

The preceding discussion demonstrates that letters of the English alphabet can be represented as strings of one's and zero's, in what is referred to as binary code. The existence of binary codes is totally independent of computers and of computing. The above coding system was created purely from the Braille method of embossing paper for the blind.

While binary coding is not intrinsically tied to computer technology, it has become a "natural language" for computers. Binary coding schemes are so useful in computer technology and so widely implemented that they are often thought to be synonymous with digital electronic computing. Now that we appreciate the fact that binary encoding has an independent life of its own, we will turn to its use in computer technology. It is through binary coding that we will be able to discuss representations of text in magnetic media.

ASCII Code

Digital computers are designed to read, store and manipulate code written in binary form. In order to perform computations the binary system of arithmetic is employed in which a 2 is represented by a 0 in the first position and a 1 in the second position 10, which would be interpreted as a ten in the base ten system. Other binary numbers are 100, to represent a base ten system 4, and 1000, to represent a base ten system 8.

In the binary system a one in the N+1 place setting represents the value of a 2 raised to the Nth power. Therefore the 1000 symbol is not a thousand as it is in the base ten system but an eight since a one in the fourth place represents 2 raised to the third power or 8.

We need not discuss binary arithmetic in detail at this juncture since we are concentrating on the coding of text. *Binary coding systems for text do not depend upon the binary number system or on binary arithmetic.*

The coding scheme most commonly employed is the American Standards Code for Information Interchange (ASCII, pronounced "as-key"). Just as with the Braille system, this is one of many possible coding systems. Alternative representations are used, including the Binary Coded Decimal (BCD) system and the Extended Binary Coded Decimal Interchange Code (EBCDIC). As long as consistent usage is maintained, it does not matter which scheme is employed.

In ASCII, code "A" is presented as (100 0001) while W is represented by (101

0111). We note that 7 binary terms are employed. The full ASCII code representation is shown in Table #2. Each binary term is known as a "bit." Since computers are designed to transmit and process 8 bits simultaneously the ASCII code can be expanded to merely have a zero preceding each term in order to create an 8-bit unit.

The first position in an 8-bit unit, known as a "byte," can be utilized effectively in a system that checks for errors. Error checking is needed because 1's and 0's can be mistaken for each other during information transmission or processing. These mistakes can arise because of faulty components, stray voltages from external sources such as a lightning storm, and the various kinds of "noise" that give rise, for example, to static on a telephone line.

A method of checking for such errors is based on there always being an even or odd number of 1's in each 8-bit term. A requirement of an even number is said to be a check on "even parity." An odd number of 1's is referred to as "odd parity." In such schemes the first bit can be adjusted so that the entire byte has either an odd or an even number of 1's. If there is no requirement on even or odd numbers of one's then parity is absent and the first bit is simply adjusted to be zero in all cases.

It is possible to code text using the ASCII scheme by setting out a string of marks on a magnetic medium. ASCII coding, while developed for use with computing, is a general scheme that could be used in other circumstances. For example it is possible to have direct ASCII representation for the blind by using an embossed 7- or 8-dot system instead of the Braille 6-dot system. ASCII coding would then be serving as a representation of the alphabet for the blind without any connection to computers or computing.

Magnetic coding of text involves the creation of a two-valued magnetic characteristic in some suitable medium. Magnetic coding technology has been a crucial factor in computer development. Vast research and development efforts have sought to code magnetic information on increasingly small regions while increasing the speed and accuracy of the placement as well as retrieval of that information.

Magnetic Recording

Once one decides to use the ASCII coding system, the task of placing text on magnetic media is reduced to altering the state of the magnetic material. A small region must be manipulated to be in one of two states. Binary marking of the material allows the placement of a string of 8 individual bits that designate each ASCII character. By placing characters together words are constructed. These words are separated by spaces, which are also ASCII characters. Other actions that are needed in creating a formatted and printed text are also part of the ASCII coding system. These include carriage returns, instructions to printers to underline, and other information that facilitate printing or display processes.

Several desirable characteristics for material used in magnetic recording can be cited. The smaller the space for the magnetic marking the more information that can be contained on a given area of the material. It is also desirable that the information be stable, i. e. not change in a haphazard fashion after it is recorded. Speed and ease of placement of information onto the medium is sought, as are the

same characteristics in "reading" or observing the state of the medium. Both placement of information onto the medium and "reading" or retrieving the information should be speedy and easy.

The essential mechanisms used to record and to read magnetic information are based upon two fundamental principles of physics. These principles are outlined below in the context of the earliest form of magnetic storage—annular rings of magnetic material having a diameter of several millimeters. These rings or cores were first used in the development of a computer at MIT in 1951 known as Whirlwind.

1. *The first principle* concerns the creation of a magnetic force by an electric current. When a small current flows through a wire near material containing individual atoms having magnetic properties, then atoms in a small region turn in the direction of a magnetic force created by the current. Current in a wire external to the material turns the atomic magnets in one of two directions. These atomic magnets orient themselves in the same way that a compass, which is a small magnet, orients itself in the magnetic field of the earth. Under the right conditions of temperature and structure of the material, these regions of magnetism stay in place and hold the binary code. Magnets pointing in one direction are designated as 1's while magnets in the opposite direction are 0's. In magnetized annular cores magnets align themselves either in a clockwise or a counterclockwise direction. The identification is arbitrary–only a consistent approach is required.

2. *The second principle* concerns the electric voltage generated by a rotating magnet. Reading of the coded information takes place by pulsing a current near the coded region to see if it can be turned into a new orientation. When a magnet rotates it creates an electric force that can be measured, thus revealing the completion of the event. In our daily lives we are constantly taking advantage of this principle since rotating magnets are integral components of electric generating stations. Whether steam or hydro-power turns a turbine, some force leads to the rotation of magnets for the generation of electricity.

When magnetically encoded material is observed by first pulsing a current near the material there will be no responding electric force if there was no magnetically coded region initially. Since no change of magnetic direction takes place, no electric force results from that action. Also, if the local magnet is initially in the direction of the twist from the test pulse there will also be no force resulting from a rotating local magnet. Finally, when there is a local magnetic code in place and the measurement pulse succeeds in twisting it into a new direction, then an electric signal will be observed. An additional reverse twist will be needed if one wishes to leave the memory in the initial state that existed prior to the observation.

Hence there are three possible responses to a current in a direction that would create *clockwise* magnetic orientation:

Initial Condition	*Result*
no magnetism	no twisting of magnetic field
clockwise magnetism	no twisting of magnetic field

counter-clockwise magnetism	twisting resulting in the measurement of an electric voltage

These procedures for encoding and observing magnetic information have advanced at a remarkable rate since they first became feasible in the early 50s.

A significant development that enhanced the effectiveness of magnetic encoding was use of surfaces coated with a thin layer of magnetic material. Such surfaces replaced the annular cores. On such a surface a small oblong cluster of iron oxide molecules (as one example) can be aligned by an external magnetic field in a direction that is independent of the alignment of neighboring clusters. These local domains of magnetism provide the physical basis for high density magnetic storage on thin circular disks.

Writing on such disks is accomplished by placing the magnetic film in the gap of a magnet that is wrapped with a wire that can carry a current. When a current pulse flows in the wire an increase of magnetism in the gap orients local domains. The reading process is accomplished by having magnetic regions move through the gap, thereby changing the magnetism in the reading head. This changing magnetism induces an electric current in the wire coil. That resulting current then carries the information that a particular bit was stored on the disk. This method of reading does not alter the orientation of the stored magnetic information.

Magnetic Storage Density

A measure of the capacity of magnetic material to store information is the number of bytes or ASCII characters that can be held in a unit of surface area. This is a number which has been increasing rapidly since 1954. In order to appreciate the significance of magnetic storage densities we can compare magnetic densities with those of typed characters on paper as well as the density of photographic images of characters on microfilm.

A line of type on a page such as this might contain between 70 and 80 characters including spaces and the page itself might contain between 50 and 60 lines. If we use as our reference standard for a page 80 characters per line and 50 lines, then there are 4000 characters per page. Given the area of a standard page as 8 and 1/2 inches by 11.0 inches or 93.5 sq. in., the information density on a normal page is 4000 bytes per 93.5 sq. in. or 43 *bytes per square inch.*

A book card of microfiche has 390 pages on an available area of 18.6 sq. in. or 390 x 4,000 characters or bytes per 18.6 sq. in. resulting in a density of about *84,000 bytes per square inch.* The limit of microfiche is about ten times that density or a number in the range of *1 million bytes per square inch.*

Graph #1 with a chart containing statistics for magnetic storage shows that in 1954 an IBM 650 computer with a drum-shaped storage device held nearly 100 bytes per square inch. That capacity is equal to about two-and-one-half times the density of a typewritten page. An analysis of the magnetic storage graph shows that it wasn't until 1978 that magnetic storage density equaled that of ultrafiche.

The graph illustrating the changes with time of storage density on magnetic media helps tell the story of the phenomenal progress of information technology

during the past three decades. An understanding of this type of change also helps us anticipate the progress that we might expect during the next three decades.

It is essential to realize in examining that graph that the vertical scale is not linear. This means that as we move up the scale from one point to another that is twice as high, we are not brought to a value that is twice the original value! Rather, the increase is much greater.

(The vertical axis is calibrated in bits per square inch rather than bytes per square inch, but since one is simply 8 times the other it tells the same story.)

Examine the value of density at the year 1954.5 (i. e. half way between 1954 and 1955). You will note that the density of magnetic storage for the straight line segment is 1,000 bits/square inch. Now move along the horizontal axis a time period of just five years to 1959.5 (i. e. half way between 1959 and 1960) where you will note that the density line is twice as high above the horizontal axis, but its value is now 10,000 bits/square inch. This tells us that in a period of five years the density has increased by a factor of *ten*. Moving along to 1964.5 we again find that the density has increased by a factor of ten again to 100,000 bits/sq. in. This rate of increase is sustained up to 1969.5 where the density value is again ten times greater after only five years and hits the 1 million bits per sq. in. value. After 1969.5 the rate of increase slows down but it still increases at a rate of a factor of ten in about ten years. Since there are two distinct periods with different rates of change, the period before and after 1969.5 are characterized by two different straight lines on this graph.

This type of nonlinear behavior is known as exponential growth since the value being examined is growing at a rate varying with the number ten raised to a power of time. Linear growth would have values proportional to time itself.

In the history of mankind, it is rare to find technological capacity expanding exponentially.

The chart itself is known as a semi-logarithm graph. Many phenomena in the natural world follow a pattern of exponential change. Cell division in which doublings are constantly taking place follows such a pattern, as does the decrease of radiation intensity from a radioactive source.

In the history of mankind, it is rare to find technological capacity expanding exponentially. Think of major technologies of the twentieth century such as automobiles and planes. Speeds of these devices have increased through the years but the progress has been closer to linear and has saturated fairly quickly. You would not need to utilize a semi-logarithmic display to chart those changes. To help grasp the drama of what has been unfolding you might try to plot changes in magnetic density versus time without using semi-logarithmic graph paper to see what problems you confront in trying to sensibly display the data.

A faster train, automobile or plane is probably costlier than its predecessor and may or may not be commercially viable. Concorde airplanes and supersonic aircraft in general have not as yet proven

competitive in spite of greater speed.

Information technology changes have been extraordinary since improvements in capability have been coupled with concomitant cost reductions. Enhanced magnetic storage density has gone hand-in-hand with a decrease in the cost of storing an individual bit. Furthermore, performance characteristics such as transfer times for storage and retrieval have improved steadily, providing greater ease in using these components in manufactured systems.

Amazingly, the storage technology improvements of the past three decades are only part of the story of the information technology revolution. Similar progress has been made in the fabrication of processing elements on individual chips and in the speed of processor performance. In each case, there has been a decrease of price associated with a corresponding increase in performance. Also, as in the case of magnetic storage, it is reasonable to project that these changes will continue for the next two or three decades, at rates that may be somewhat slower than during the past thirty years, but nevertheless dramatic.

As a simplified model for the changes in information technology, consider three sub-technologies changing at the rate of a factor of ten every ten years. If a measure of the overall improvement in performance could be considered to be the product of these three factors then performance would be changing at the rate of a thousand-fold improvement per decade with associated reduced costs. Change over a thirty-year period at that rate yields a billion-fold improvement per decade with associated reduced costs. While this model is meant to be suggestive rather than precise, it provides some insight into what has been happening and will continue to happen as improvements take place in the field of information technology during the next several decades.

Text on Optical Media

In placing binary code onto any medium it is necessary to have two distinguishable marking states so that one state can be identified with a 1 and the other identified with a 0. On paper that marking can be done with typed numbers, or embossed with dots. On magnetic material the marking can be done by orienting the local state of magnetism in a precise manner. We now examine another coding process that utilizes laser technology.

Because of their potential advantages for high intensity, pureness of frequency and ease of creating parallel rays of light, lasers are attractive information encoding devices. Lasers can have sufficient intensity to cut or burn various materials. Lasers are used routinely in fields as diverse as eye surgery, metal parts fabrication and the cutting of fabric for clothing.

Optical digital disks are devices that have binary code embedded in them by lasers that burn pits onto a surface or which alter the state of the material in other ways. The significance of the change brought about by the laser is that the properties of reflection of light are changed at the location where the transformation took place.

Hence, binary code is transcribed onto an optical disk surface with a high-intensity laser and then read from the disk by analyzing reflections from that location using a low-intensity laser.

As with microform, the limit to how much data can be embedded onto a given area is limited by the finite size of the

laser beam. The smallest spot will have a radius that is about the size of the wavelength of the light itself or about 0.00006 centimeters. The area of this spot would be 0. 00000001 square centimeters. In scientific notation these numbers are 6 x 10E(-5) centimeter and 1 x 10E(-8) square centimeters respectively. This notation uses the number 10 raised to a negative exponent which is the same as the reciprocal of the positive power. For example, 10E(-1) is one-tenth or one over ten and 10E(-2) is one one-hundredth.

The maximum density of spots per square centimeter is equal to a square centimeter divided by the size of an individual spot. This figure, which is one hundred million spots per square centimeter, is unrealistically large since space is needed between spots and space is needed for other organizational features of the disk. Nevertheless it is the maximum density possible for spots made with visible light. In order to compare it with the density of characters per square inch on magnetic media it is necessary to multiply by 6.45 to convert from square centimeter to density per square inch and then to divide by eight to convert bits to bytes. The result is close to one hundred million bytes per square inch.

A twelve-inch diameter disk has an area in excess of 100 square inches leading to a theoretical maximum capacity for such a disk of 10 billion characters or 10 gigabytes per side. In fact commercial disks today are able to achieve one or two gigabytes per side.

Optical digital disks can record anything that can be coded in digital form. Possibilities include ASCII coded text, digital music, digital television, computer software, etc.. The rapid rise in popularity of digital music on optical digital disks called compact disks has been a great stimulus to the commercial development of this technology.

Optical digital disk technology today has capabilities for the production of prerecorded disks as well as for disks that can be encoded on site. These disks have generally been coded using techniques that are non-reversible. Usually pits have been burned into their surfaces rendering them non-erasable. Various technologies are in the trial stages however for erasable procedures and these should become available during the next three to five years.

An optical digital storage device is now available as a strip on a credit card-sized object. These cards could potentially have four stripes on each side and hold 16 million bytes or 6,400 pages of text.

Optical disks have great advantages in terms of their high capacity and their durability. Unlike magnetic disks that can easily be degraded or damaged, the optical disks are resilient objects that can hold their data for at least ten years and possibly much longer. Furthermore, their cost is low and will allow many novel applications.

For example, a type of optical digital storage device is now available as a strip on a card the size of a credit card. This card, which is manufactured by the Drexon Technology Corporation, holds 2 million bytes of information, which is equivalent to about 800 pages of typical typed text. These cards potentially could

have four stripes on each side and hold 16 million bytes or 6,400 pages of text.

Health insurance companies are planning to have their subscribers carry Drexon cards with an individual's full medical history encoded. The U. S. Army plans to use such cards as identification cards for soldiers containing personal data including health, training, and service records. Cards such as these can be updated as needed, cannot have segments erased or modified, and can be carried in a purse or wallet.

Service Sector Automation

This brief study of Technologies for Text has dealt with clay tablets, writing on paper, printing, typed manuscripts, magnetic storage of text and optical digital records. These various storage technologies occupy but one corner of the broader domain of information technology. The significance of the Technologies for Text can be illustrated with applications that show their impact on society as well as their relationship to various areas of information technology.

The context for these examples is a segment of the economy that is commonly referred to as the service sector. Before proceeding it is helpful to clarify what is meant by the service sector. In so doing it is also necessary to say more about information technology itself since the dramatic development of information technology gives shape and meaning to the evolution of the service sector.

In relating Technologies of Text to the service sector a double purpose is served: domains of application are presented for the technologies of text and an important sector of society is examined. While the service sector is increasingly important as a social and economic entity in society, it is the most elusive sector to identify. The agricultural and manufacturing sectors can be defined through their output. In contrast, the service sector is most readily identified by its methodology. That methodology is often the processing of information.

A facile definition for the service sector that is popular with the press is the "domain of the knowledge worker." While that definition may satisfy our need for glorification it does not satisfy our need for clarification.

The manufacturing sector is not only easier to categorize, but the impact of information technology on that sector is more readily evident through the dramatic substitution of machines for men. What is more complex and subtle is the substitution of machines for human effort in the service sector. Here the substitution is not total. In manufacturing there are significant examples in which there is a clear replacement or extension of *muscle* power by innovative technologies. In the service sector, technological impact is often a mix of relieving human workers of manipulative tasks, while enhancing *mental* processing in some of the remaining tasks.

There is no uncertainty about how one should categorize the replacement of humans by robots in welding and painting jobs in an automobile fabrication plant. This contrasts with the complexity and subtlety of service sector automation in which diverse technologies come into play. These include both communications and computing technologies which are categorized under the combined rubric of "information technology."

Various aspects of information tech-

nology have contributed to the evolution of the service sector for more than one hundred and fifty years. Development started perhaps with the first commercially successful calculator, invented in 1820. Other important 19th century inventions included the telephone and the dictating machine. These, together with the typewriter, set the stage for contributions of the computer and telecommunications technologies in the twentieth century.

Increasingly, we refer to this evolving environment as evidence of the "information age." If asked for the date on which that age dawned, one would be hard pressed to respond with a specific moment. The "information age" did not come up over the horizon one fine day. Rather many pieces came into place over a period of years. Many of these pieces belong to the realm of computers and many belong to the realm of communications. It is the melding of the two technologies of computers and communications that has provided society with a revolutionary new infrastructure. The thread which binds that infrastructure together and which makes it whole is "digitization." The process of analog to digital conversion in which entities, including television signals are changed into a stream of pulses of one's and zero's, provides the basis for this unification. Information technologies of telephone, radio, television, and photography can all be stored, processed and transformed in digital form by computers. Furthermore, communications technologies that initially supported voice connections over telephone links, now have modes in which computers can be connected for the full exchange of digital information.

In citing the emergence of the information age as a revolutionary development, the word "revolutionary" was used advisedly. Revolutions imply dramatic changes or transformations. A revolutionary step is discontinuous not incremental. The blending of communications and computer technologies meets that test. Digitalized communications systems, such as digital television, are quite unlike the analog television that predated it. Digital signals can be refined and mixed in ways that were impossible prior to digitization. Similarly computers that are linked via communications networks are capable of feats that were unattainable for isolated units.

It is the ability of hardware and software to manipulate the digitized contents of computer-communications systems that creates a difference in kind from earlier technological stages. This manipulation of information in environments that employ storage, retrieval and communication systems is in its infancy. Future generations are likely to look back on the 1970s and 1980s as an era of "primitive" information technologies, but they are likely to agree that the period was a watershed in the evolution of society.

The power and significance of information technology is perhaps best elucidated through an examination of its impact in the service sector. Just as automation on the farm or in the factory has transformed those centers for employment and production, the advent of information technology is transforming the service sector. The striking difference here is that changes are taking place in functionality that is human centered rather than land centered, animal centered or thing centered. Some of these changes which seemed magical a few years ago have become commonplace. One of the

most profound manifestations of information technology has been word processing. Word processing which was unimagined by most people in the early 70's has become pervasive and is now taken for granted. In some locales word processing is now included as part of the regular school curriculum in the first grade.

Other profound changes due to information technology can be found in transformations of various professions. For example, a librarian at mid-career today entered a field that used totally different techniques for the organization of the library itself as well as for the search and retrieval of information. Not too long ago, libraries were repositories where paper, file cards and quill pens sufficed as tools of the trade. Similarly, the banking field has undergone a transformation with the use of electronic communications systems, and computing technologies including Electronic Funds Transfers (EFT), Automated Teller Machines (ATM), banking by computer, etc. Librarians and bankers among others have had their work comprehensively transformed by information technology.

The service sector includes activities in the economy having workers who are providing services directly to customers, such as department store clerks and supermarket cashiers. A broader view of the service sector incorporates office workers and others involved in the support of services to customers. When treated separately this fourth sector of the workforce is denoted as knowledge workers. A useful definition of the service sector, however, can encompass all activities that lie outside the manufacturing/ blue collar and agricultural sectors. This approach would place banking, law, medicine, insurance, entertainment, and education in the service sector.

During the course of the 20th century the shift in work force in the United States has been dramatic in its movement away from the agricultural sector and toward the service sector. In coming years many anticipate further reduction in the manufacturing, blue collar areas and a rise in the service arena. The following table summarizes work force data from the U. S. Department of Commerce:

Year	Agricultural	Blue Collar	Service
	%	%	%
1900	38	36	26
1940	17	40	43
1980	3	32	65

The transformation of the American economy has been so strongly away from the agricultural sector as a place for employment toward the industrial and service areas that during the next decade the Department of Labor Statistics expects that the number of engineers (1,331,000 in 1984) will exceed the number of farmers and farm workers(1,442,000 in 1984). The engineering work force is projected to grow to 1,811,000 by 1995 while the farming work force shrinks to 1,380,000 in that same year.

Shifts taking place in the economy are away from muscle and motor skill jobs toward mental information processing jobs. Many of the fastest growing employment areas are directly related to computer design, fabrication, and utilization. In 1995, compared with 1984 statistics, employment for computer programmers is expected to grow by 72 percent, computer systems analysts and data processors by 69 percent, while growth for electrical engineers, technicians and data

processing equipment repair workers are all expected to be in the low to mid 50 percent range.

Not all changes are in high technology fields. The leisure industries are among the major growth areas with a 44 percent increase in employment anticipated for travel agents, 29 percent for cosmetologists and related workers and 28 percent for bartenders. Even within this group, the work of travel agents is heavily influenced by information technology while robotic bartenders and hair stylists are within the realm of possibility.

Information technologies are a lively component of the economy and present many employment opportunities. Not only are information technologies changing the economic balance, but employment opportunities and the nature of work experience are being transformed within many fields.

These statistics on work force employment do not say anything about the nature or quality of that employment nor about the relative productivity of the jobs that are being done. For example, the productivity of the agricultural sector has increased enormously while the agricultural work force has declined precipitously. To date many organizations have achieved limited productivity increases through the automation of office work. Analyses along these lines provide opportunities for independent study.

Applications and Case Studies

Library Automation

A clear example of information technology's role in automation of the service sector is the introduction of new text technologies into libraries. For many years there had been little change in the organization and functional capabilities of libraries. Today we find that almost every information technology development has applicability in the library storage systems, computers, networks, improved software and display systems. A full review of library automation requires a thorough analysis of the field of information technology itself.

This presentation is limited to technologies for text storage in the library environment. Our attention will focus on some library applications of optical digital disks.

A two-sided twelve-inch diameter optical digital disk can hold 2 x 10 E9 bytes or two gigabytes. If we assume that a page contains 4,000 characters or bytes and that there are 500 pages in a book then we are equating a book with 2 million bytes (2 megabytes) of digital storage. Since a billion is equal to a thousand millions we find that a two-sided optical digital disk can hold 1,000 books.

The question arises as to how many books there are in a library. A college library would generally have several hundred thousand monographs and a large research university would have in excess of a million. The New York City Research Library holds 7 and 1/2 million volumes while the Harvard University Library has more than 10 million volumes. Harvard is the second largest library in the United States and is somewhat more than half the size of the Library of Congress, which has 18 million volumes.

Simple arithmetic tells us that the Library of Congress monograph collection can be placed onto 18,000 optical digital

disks using 1986 technology. If we assume that disks can be stacked with a packing volume of 8 to the inch, then 18,000 disks would have a storage requirement of 2,250 inches of shelf space or approximately 200 running feet.

An ordinary large living room or family room could hold the entire Library of Congress if its contents were encoded onto optical digital disks.

That amount of storage space can be placed on two walls, each twenty feet long and able to accommodate five shelves. An ordinary large living room or family room could hold the entire Library of Congress if its contents were encoded onto optical digital disks.

The Library of Congress is currently pursuing an optical digital disk project that does not involve ASCII coded representations of pages. Instead, each page is scanned by an optical device that records the light and dark spots and places digital information of this image onto a disk. The dots are fine grained with about 4,000 dots representing every square inch of the page's image. This procedure is called "bit-mapped scanning."

Technology is also available that would place a page of text in ASCII coded form onto a disk utilizing an Optical Character Recognition device. In such an instrument the optical scanning of individual characters is able to recognize individual fonts and transform them into ASCII code.

Digital scanning machines and optical character recognition (OCR) machines are important technologies for text and image manipulation. The bit-mapped scan occupied much larger segments of memory than an ASCII representat. However, it is a faster process which can handle images and diagrams and makes fewer notable errors. ASCII coded representations, however, provide the advantage of automated text processing capabilities. (Further review of these technologies is left for possible homework or project assignments.)

While the placement of a major library onto disk would be a huge undertaking, we see that it is feasible to carry the equivalent of the Harvard Library in a small to medium-sized truck. Multiple copies of libraries could be made, and certainly all new books (already in ASCII format having been created with text processors) could be distributed easily on optical disks. Authors could hand out business cards that had their recent works printed in optical format! The economic implications of optical disk production for the publishing industry will be significant. It is not yet clear how publishing will be transformed, not only by optical digital disks, but by other computer and communications innovations as well.

The impact on the publishing of professional journals is also difficult to discern. One can imagine all of the world's monthly publications in a given field, such as mathematics or psychology, being placed on a single optical disk and sent as a single subscription item to all professionals in that field. With a player and appropriate search software individuals could become independent of libraries.

Currently services are available to libraries that provide the full text of various journals via telecommunications links. The direct sale of these journals on

read only optical disks (CD-ROM) is now being tested. While it is not clear how these new distribution mechanisms will evolve, it is certain that the organization and structure of libraries will continue to change rapidly in the next decade.

One of the first optical digital disk commercial products for use is libraries (as well as in book stores) is a CD ROM that provides a database of books in print. This disk, which is being issued by the nation's largest book distributor, will provide instant access to more than 350,000 books in print. If one assumes that each citation contains about 300 bytes, then the data content of the disk would be at least 100 megabytes. CD ROM are 5.25 inch diameter disks holding a maximum of 600 megabytes. In addition to the original data, the disk also must hold extensive files and search software. In the current commercial scheme libraries and book stores must buy an original disk after which they receive monthly updates on floppy diskette and updated CD ROM's on a quarterly basis.

Insurance Office Automation

Applications of information technology in the office environment are not simply mechanisms for changing the productivity of individual workers. The impact of computer technologies, text storage and retrieval systems, software manipulation systems, networking and communications systems restructure job functions and work relationships.

The insurance business is one of the most text intensive. Documents, records and reports from a variety of sources must be processed and correlated. An essential component of the work environment is the file. Digital text and image processing provides the possibility of maintaining fully electronic files. Not only can individual items be added to case files but files can be shared and reviewed by various insurance personnel using multiple access communications capabilities. Files can also be reviewed and analyzed by multiple personnel using powerful software routines. Evaluations can be checked for adherence to contract obligations, legal requirements and corporate practice through automatic processing.

In such an environment someone whose previous job was data entry might be able to perform higher level tasks. Similarly, someone who before office automation performed higher level tasks might now be required to enter data and engage in some routine processing. Job functions easily become many faceted, involving both higher and lower level responsibilities. Certain routine procedures can disappear altogether and certain supervisory tasks can also be eliminated through the application of information technology.

The insurance industry is not only an important testing ground for uses of information technology, it is one of the most significant service industries in the United States. This is true in terms of its dollar volume and in terms of its employment characteristics. In 1980, one million Americans were working as "administrative support personnel" in the insurance industry out of a total of 14 million such workers. The insurance industry is also one of the most information technology intensive. One reliable estimate attributes 16 percent of IBM's installed base to this one industry.

A seminal research study on the impact of information technology on work in the insurance industry was carried out

by Barbara Baran of the University of California-Berkeley's Institute of Urban and Regional Development. She was interested in changes in job function and in possible differential effects on the female workforce. Her study was entitled, "Office Automation and Women's Work: The Technological Transformation of the Insurance Industry."

> **Jobs may become more boring, stressful, and unsatisfying as the machines make more of the decisions.**

Beginning in the late 1970's Dr. Baran observed significant changes in the kind of automation that moved away from, "... automating discrete tasks (e. g., typing, calculating) to rationalizing an entire procedure (e. g. new business issuance, claims processing) to restructuring and integrating all the procedures involved in a particular division, product line, or group of product lines."

In addition to job restructuring, organizational changes began to take place as technology relocated information that had previously been used as part of a power relationship. People needed to relate to each other differently when they could access the same information.

Information technology also changed organizations in terms of physical arrangements within a site and the geographic siting of related units. Some workers could be placed in lower overhead facilities since communications links overcame the barrier of distance. Also some work could be farmed out to piece workers such as women with young children who could perform tasks from their homes.

Baran observes that, over the next decade, with efficiency increases, the overall number of employees in the insurance field ought to decrease (assuming a constant workload). These changes will likely involve the elimination of more routine tasks and an upgrading of job classifications. However, occupational mobility may decrease and the quality of work life may also decrease. These changes would be due to a highly structured environment and one in which there are greater discontinuities between the new job levels so that it becomes harder to bridge from one to another. Jobs may become more boring, stressful (as the monitoring capabilities of management enable supervisors to track every keystroke of an employee) and unsatisfying as the machines make more of the decisions.

During the period of increased automation from 1970 to 1982 the percentage of women employed by insurance companies rose from 54 percent to 61 percent, representing the largest increase in share of professional employment by women of any major sector in the American economy. These increases included greater representation of women in professional, managerial and technical positions. However, the wage rate for the entire industry remains relatively low and with the possibly declining quality of work life this newly found female participation in professional positions may not be a positive development.

In mid-1986 a court case was pending in California involving eight women who were suing a major insurance company for alleged exploitation. They transferred

to at-home work as claims processors in order to have more time with their children, to have flexibility in their schedules and to avoid expenses for commuting, clothing and child care.

The reality of their experience did not match their expectations. They say that in order to meet company quotas they were spending up to 15 hours per day at their terminals. Furthermore, they lost various fringe benefits since they were no longer considered to be regular employees. We see that society is only beginning to recognize the various implications of automation in the service sector.

These observations alert us to the need to structure automation and the reorganized workplace in a fashion that not only increases productivity but makes the work more humane. Many choices are possible for the structure of the new world of work in an automated service sector. The problem will be to create environments that will be able to tap human enthusiasm and creativity along with contributions from ineluctable electronic logic circuits.

Professor Lester Thurow of MIT has pointed out that the U. S. is dangerously behind other industrial societies in productivity improvement. Improvements in the manufacturing/blue collar realm are impressive. However, productivity gains have been wiped out by a massive infusion of labor into the white collar sector without concomitant increases in output. Information technology impact on the service sector has yet to benefit the larger society. Studies such as those by Barbara Baran are needed to help guide the way, but knowledge of the technology itself and a realistic evaluation of its continuing changes will also be crucial for success.

Management expert Peter F. Drucker recently commented on the national need to increase productivity through automation in all sectors. He wrote: "...we have learned that installing new machinery in the office will not by itself result in more production or in lower costs. To be effective, office automation requires fairly radical changes in work flow, job design, job relations and staffing–and again first-line supervisors are the key. No one quite yet knows what jobs will look like in the automated office–all we know is that they will be quite different."

Hospital Automation

As we look toward the future of service sector automation, one of the most interesting and exciting possibilities on the horizon is that of health care automation. Health care, a service sector category of importance to everyone, desperately needs increased productivity.

Information technology is vital to both the insurance industry and hospital services since both depend on active filing systems. Complex and diverse services are rendered by many departments and individuals, all of whom rely upon the same files. Proper health care treatment and processing requires a clear interpretation of past experience and timely updating of new information in the filing system. Hospital patient files can easily consist of hundreds of pages. These include computer generated forms and the output of various diagnostic procedures which can be fully coded in digital format. Much of the material is handwritten and can be entered via digital image scanners. This latter capability is useful but not as useful as full text in ASCII form.

A major breakthrough in recordkeeping is the ability of optical disk technology to maintain full files in digital form from all of the test and instrument analysis areas. X-Rays, EKG's, CAT scans, NMR scans, and other testing technologies are increasingly in, or can be readily converted to, digital form. Every aspect of a patient's record can be maintained on the same optical disk. It is also possible to circumvent use of handwritten notations by electronically filing audio voice comments or ultimately using voice recognition systems to encode voice messages in ASCII format.

Some of these capabilities have not yet become technologically feasible, but the day is fast approaching when systems along these lines will be operational.

Other Areas

The selected material presented above on library, office, and health care automation touches on limited aspects of these domains. Technologies for text are in fact restructuring each of these areas. Many additional applications of these information technologies could provide illuminating case studies. Possiblities include banking, finance, publishing, criminal justice, legislation, and education, among others. Further examination of these topics is left for independent study by students. Even if they are not pursued formally, the tide of events is such that these and other consequences of technologies of text will surely intrude with increasing force in all our lives.

Exercises for students:

1. Choose one of the following technologies and report on its capabilities to electronically process text: Optical Character Recognition, Optical Scanning, and Facsimile Machines.

2. Review the use of automated files in the law enforcement field including the use of electronic representation of photographic images and of fingerprints.

3. Visit offices in locations such as schools, hospitals, insurance companies, police departments, newspapers, etc., to observe their uses of technologies for text and related information technologies. Comment on the characteristics of the technologies that are used and on the transformations that these technologies have produced in the workplace.

4. Show why there are 63 possible marks that can be made in Braille using two rows of three dots. The use of all six dots counts as one possible mark, but the absence of all marks (null) is excluded.

5. In the Book of Exodus in the Old Testament, section 34 states the following:

"And the Lord said unto Moses, Hew thee two tables of stone like unto the first: and I will write upon these tables the words that were on the first tables, which thou brakest. "

How much information is referred to here (i.e. number of characters)? How does this compare with the maximum amount of information that could be placed on two stone tablets which a normal adult might be expected to carry down a mountain?

6. Evaluate the storage space required for the *Iliad* of Homer on clay tablets, papyrus, printed text, microfiche, IBM PC diskettes, and on optical disk.

7. In the third act of Hamlet characters appear with the following frequency:

SPACE	E	O	T
6934	3277	2578	2557
A	S	H	N
2043	1856	1773	1741
I	R	L	D
1736	1593	1238	1099
U	M	Y	W
1014	889	783	716
F	C	G	P
629	584	478	433
B	V	K	-
410	309	255	203
J	Q	X	Z
34	27	21	14

TOTAL CHARACTERS: 35, 224

Character pairs in this same text have:

E followed by space (words ending in E, leading the list)
Space followed by T (words beginning with T)
TH
HE

Using this information design a typewriter keyboard that you think would optimize speed in typing Act III of *Hamlet*. What are the design considerations that led you to your formulation? How does your design compare with the QWERTY and DVORAK keyboards? How would you empirically test your model?

(The data on Hamlet Act III are taken from: *Scientific and Engineering Problem-Solving With the Computer*, William Ralph Bennett, Jr., Prentice-Hall, Inc., Englewood Cliffs, N.J., 1976.)

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Information Technology R & D: Critical Trends and Issues, Office of Technology Assessment Report, February 1985, OTA-CIT-268. (This report deals with the nature of information technology and development, case studies on advanced computer architecture, software engineering, fiber optics, and artificial intelligence, issues and strategies, including impacts of telecommunications deregulation, foreign programs, and science policy.)

JIIM: The Journal of Information and Image Management, Association for Information and Image Management, 1100 Wayne Ave., Silver Spring, MD, 20910. (A monthly journal with well-written semi-technical articles about all the competing technologies that are in use for document and image storage and retrieval.)

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Figure #1

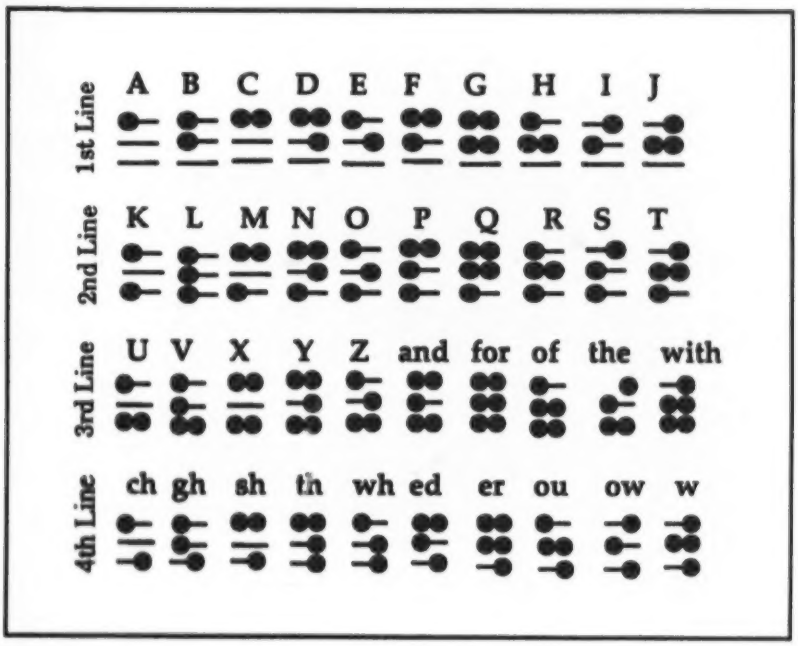
Figure #1 is a picture of a water stream. It represents the word *a*, "water." This sign furnishes us with an excellent illustration of the process by which the Sumerian script gradually lost its unwieldy pictographic character and became a phonetic system of writing. Although the Sumerian word *a*, represented by sign No. 11, was used primarily for "water," it also had the meaning "in." The word "in" is a word denoting relationship and stands for a concept which is diffcult to express pictographically. The originators of the Sumerian script had the ingenious idea that, instead of trying to invent a complicated picture-sign to represent the word "in," they could use the sign for *a*, "water," since the words sounded exactly alike. The early Sumerian scribes came to realize that a sign belonging to a given word could be used for another word with an altogether unrelated meaning if the *sounds* of the two words were identical. With the gradual spreading of this practice, the Sumerian script lost its pictographic character and tended more and more to become a purely phonetic script.

From *The Sumerians, Their History and Culture.* Samuel Noah Kramer (University of Chicago Press, 1963), pp. 303 and 305.

Figure #2: The QWERTY Keyboard

Figure #3: The DVORAK Keyboard

Table 1



The Braille alphabet. One of the most widely used alphabets for the blind.

Table #1

Table 2

American Standard Code for Information Interchange (ASCII)

ASCII Table (Format = Decimal, Hex, Octal, ASCII)

0	$00	\000	NUL^@	26	$1A	\032	SUB^Z	52	$34	\064	4	78	$4E	\116	N	104	$68	\150	h
1	$01	\001	SOH^A	27	$1B	\033	ESC^[	53	$35	\065	5	79	$4F	\117	O	105	$69	\151	i
2	$02	\002	STX^B	28	$1C	\034	FS ^\	54	$36	\066	6	80	$50	\120	P	106	$6A	\152	j
3	$03	\003	ETX^C	29	$1D	\035	GS ^]	55	$37	\067	7	81	$51	\121	Q	107	$6B	\153	k
4	$04	\004	EOT^D	30	$1E	\036	RS ^^	56	$38	\070	8	82	$52	\122	R	108	$6C	\154	l
5	$05	\005	ENQ^E	31	$1F	\037	US ^_	57	$39	\071	9	83	$53	\123	S	109	$6D	\155	m
6	$06	\006	ACK^F	32	$20	\040	SP	58	$3A	\072	:	84	$54	\124	T	110	$6E	\156	n
7	$07	\007	BEL^G	33	$21	\041	!	59	$3B	\073	;	85	$55	\125	U	111	$6F	\157	o
8	$08	\010	BS ^H	34	$22	\042	"	60	$3C	\074	<	86	$56	\126	V	112	$70	\160	p
9	$09	\011	HT ^I	35	$23	\043	#	61	$3D	\075	=	87	$57	\127	W	113	$71	\161	q
10	$0A	\012	LF ^J	36	$24	\044	$	62	$3E	\076	>	88	$58	\130	X	114	$72	\162	r
11	$0B	\013	VT ^K	37	$25	\045	%	63	$3F	\077	?	89	$59	\131	Y	115	$73	\163	s
12	$0C	\014	FF ^L	38	$26	\046	&	64	$40	\100	@	90	$5A	\132	Z	116	$74	\164	t
13	$0D	\015	CR ^M	39	$27	\047	'	65	$41	\101	A	91	$5B	\133	[	117	$75	\165	u
14	$0E	\016	SO ^N	40	$28	\050	(	66	$42	\102	B	92	$5C	\134	\	118	$76	\166	v
15	$0F	\017	SI ^O	41	$29	\051	)	67	$43	\103	C	93	$5D	\135	]	119	$77	\167	w
16	$10	\020	DLE^P	42	$2A	\052	*	68	$44	\104	D	94	$5E	\136	^	120	$78	\170	x
17	$11	\021	DC1^Q	43	$2B	\053	+	69	$45	\105	E	95	$5F	\137	_	121	$79	\171	y
18	$12	\022	DC2^R	44	$2C	\054	,	70	$46	\106	F	96	$60	\140	`	122	$7A	\172	z
19	$13	\023	DC3^S	45	$2D	\055	-	71	$47	\107	G	97	$61	\141	a	123	$7B	\173	{
20	$14	\024	DC4^T	46	$2E	\056	.	72	$48	\110	H	98	$62	\142	b	124	$7C	\174	|
21	$15	\025	NAK^U	47	$2F	\057	/	73	$49	\111	I	99	$63	\143	c	125	$7D	\175	}
22	$16	\026	SYN^V	48	$30	\060	0	74	$4A	\112	J	100	$64	\144	d	126	$7E	\176	~
23	$17	\027	ETB^W	49	$31	\061	1	75	$4B	\113	K	101	$65	\145	e	127	$7F	\177	D
24	$18	\030	CAN^X	50	$32	\062	2	76	$4C	\114	L	102	$66	\146	f		by		E
25	$19	\031	EM ^Y	51	$33	\063	3	77	$4D	\115	M	103	$67	\147	g		Bob Perez		L

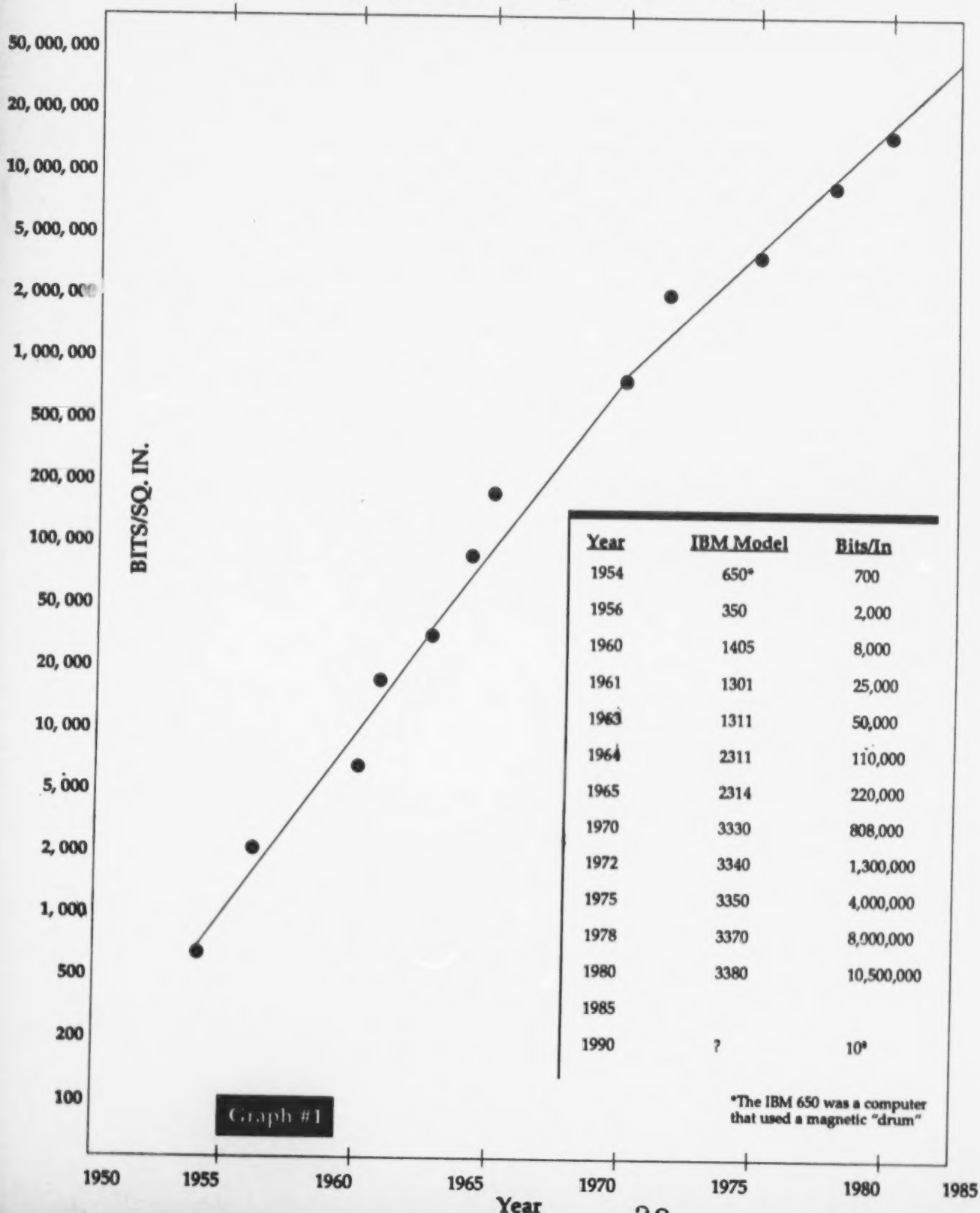
The ASCII code. The two and three-letter abbreviations denote control characters. Examples are CR (carriage return), LF (line feed), and BEL (bell).

1100001 1110110 1100100 0100000 1100001 0100000

1101110 1100011 0100000 1100100 1001100 0101111

A message coded in ASCII

Storage Density of Magnetic Disk Drives



Year	IBM Model	Bits/In
1954	650*	700
1956	350	2,000
1960	1405	8,000
1961	1301	25,000
1963	1311	50,000
1964	2311	110,000
1965	2314	220,000
1970	3330	808,000
1972	3340	1,300,000
1975	3350	4,000,000
1978	3370	8,000,000
1980	3380	10,500,000
1985		
1990	?	10⁹

*The IBM 650 was a computer that used a magnetic "drum"

Graph #1

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